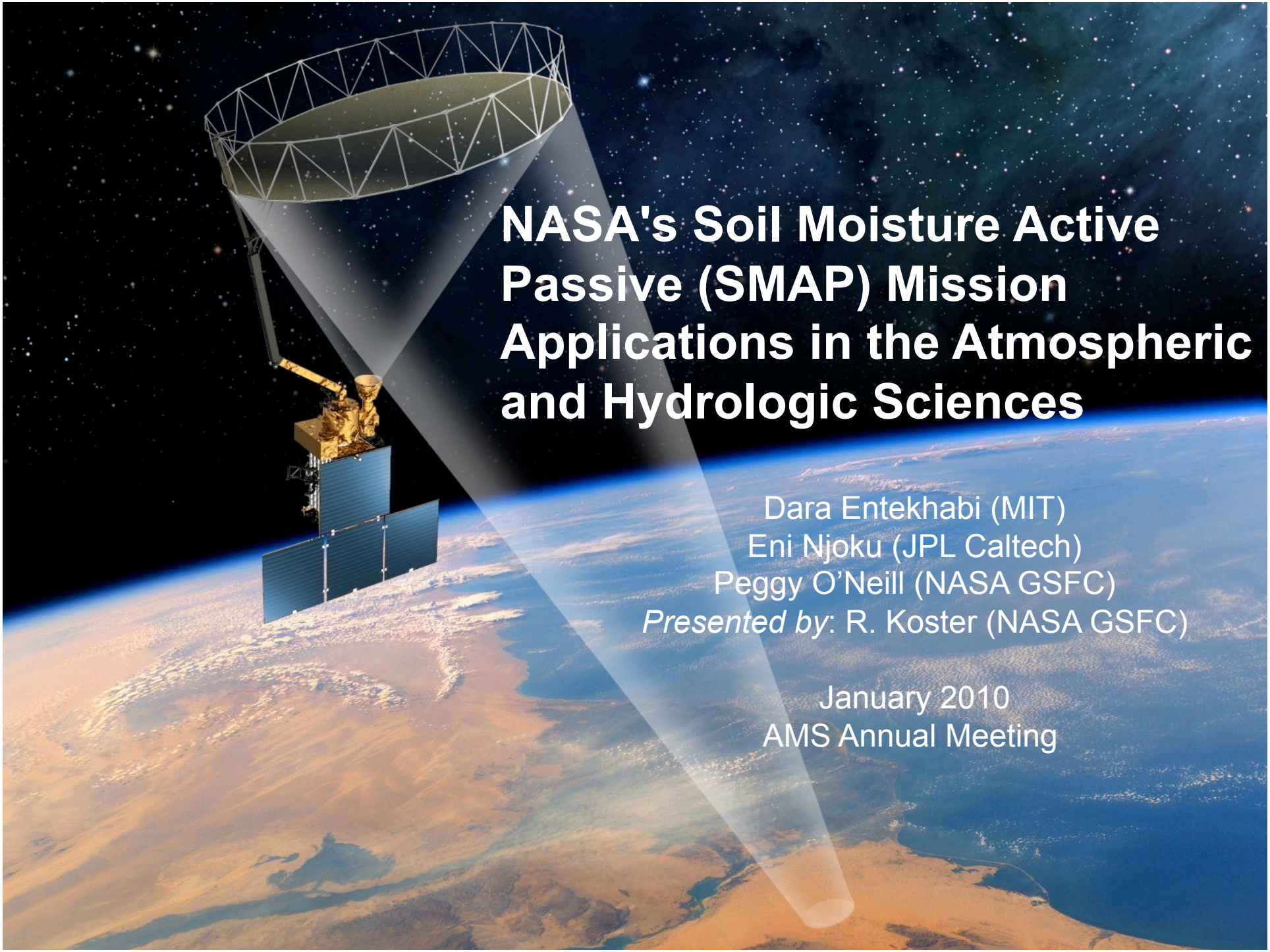


NASA's Soil Moisture Active Passive (SMAP) Mission Applications in the Atmospheric and Hydrologic Sciences

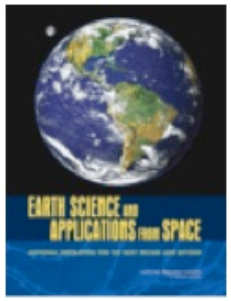
Dara Entekhabi (MIT)
Eni Njoku (JPL Caltech)
Peggy O'Neill (NASA GSFC)
Presented by: R. Koster (NASA GSFC)

January 2010
AMS Annual Meeting

National Aeronautics and Space Administration

Jet Propulsion Laboratory
California Institute of Technology
Pasadena, California

Project/Mission Overview—Mission Context



US National Research Council Report: "Earth Science and Applications from Space: National Imperatives for the next Decade and Beyond"

SMAP is one of four missions recommended by the NRC "Decadal Survey" for launch in the 2010–2013 time frame

Tier 1:	
	Soil Moisture Active Passive (SMAP)
	ICESAT II
	DESDynI
	CLARREO
Tier 2:	
	SWOT
	HYSPIRI
	ASCENDS
	GEO-CAFE
	ACE
Tier 3:	
	LIST
	PATH
	GRACE-II
	SCLP
	GACM
	3D-WINDS

- Feb 2008: NASA announces start of SMAP project
- SMAP is a directed-mission with heritage from Hydros
- Hydros risk-reduction performed during Phase A (instrument, spacecraft dynamics, science, ground system) Cancelled 2005 due to NASA budgetary constraints

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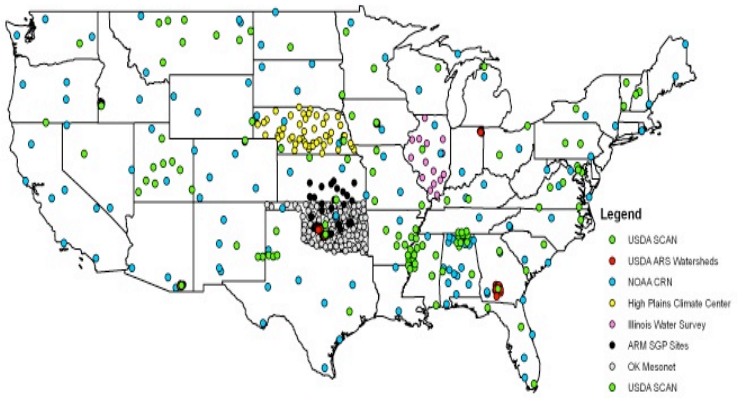
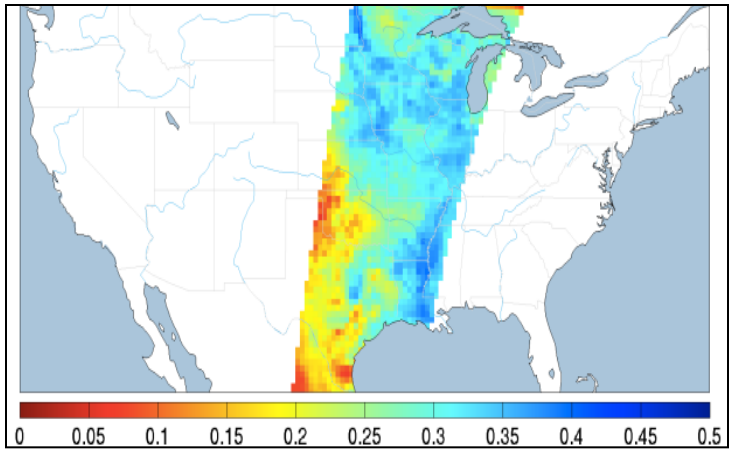
Soil Moisture Monitoring



Limitations of current approaches

- Installed in situ network has inadequate coverage, particularly at global scale
- Existing space-borne sensors have inadequate sensitivity & resolution



For soil moisture, SMAP provides:

- High revisit time (2-3 days)
- High spatial resolution (10 km)
- Depth to 5 cm (Level 2)
- Depth through the root zone (Level 4, with data assimilation)

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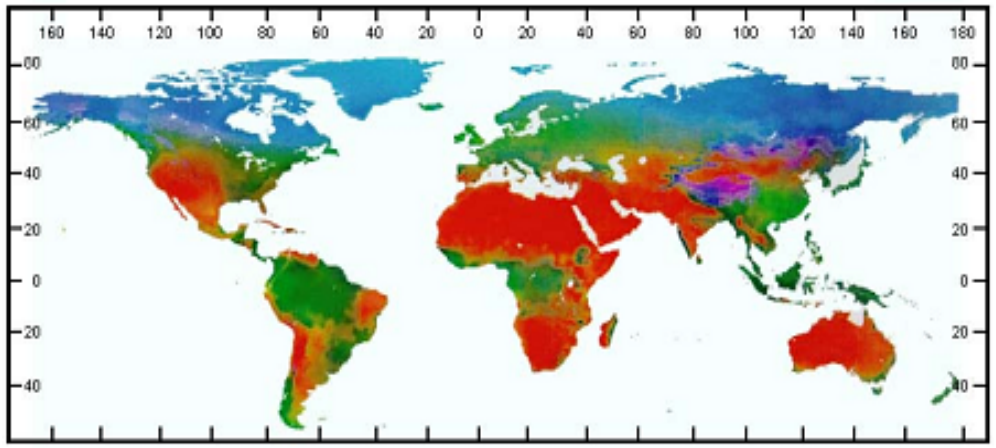
SMAP Mission: Science Objective

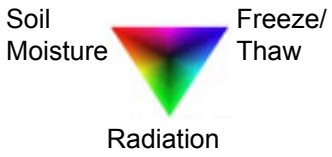
Global mapping of soil moisture and freeze/thaw state, to:

- Understand processes that link the terrestrial water, energy & carbon cycles
- Estimate global water and energy fluxes at the land surface
- Quantify net carbon flux in boreal landscapes
- Enhance weather and climate forecast skill
- Develop improved flood prediction and drought monitoring capability

Also part of SMAP mission!



Primary Controls on Land Evaporation and Biosphere Primary Productivity



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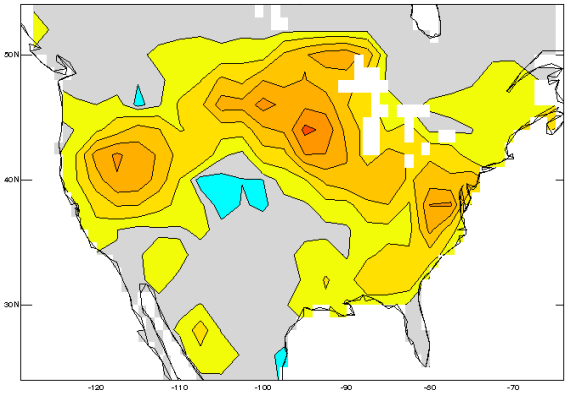
Science/Apps Driver: Seasonal Prediction

Soil moisture information contributes skill to subseasonal rainfall & temperature forecasts

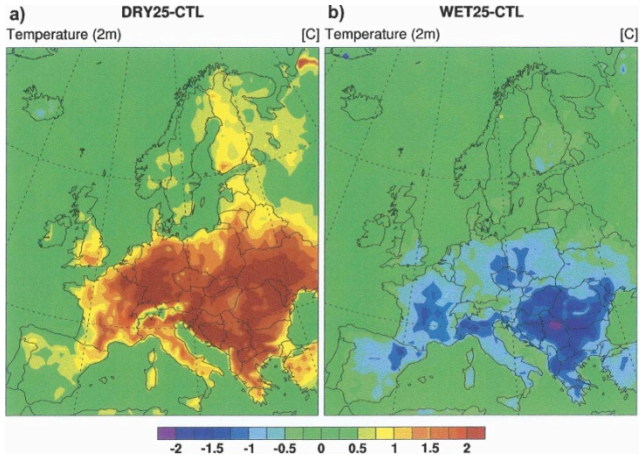
GLACE-2: Contribution of soil moisture to conditional skill (r^2) in forecasted air temperature at 31-45 days.



Conditional forecast skill: r^2 with land ICs minus that obtained w/o land ICs

(Conditioned on initial local soil moisture being in the driest or wettest quintile of its background distribution. Conditioning subsets for skill calculation vary with location.)

(Koster et al., *GRL*, in press.)



Soil moisture anomalies often precede seasonal extremes → May help in forecasting them

Simulations show that springtime soil moisture can affect subsequent summer temperatures. During the *European heat wave of 2003*, temperature anomalies may have been reduced by 40% if springtime soil moistures were not dry.

(Fischer et al., J. Climate, 20, 5089-5099, 2007).

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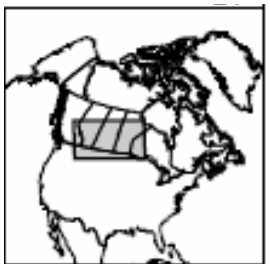
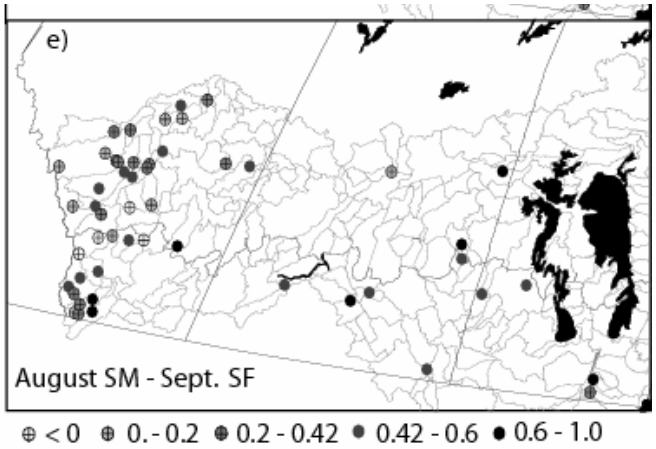
Science/Apps Driver: Hydrological Prediction

Soil moisture information can contribute skill to streamflow forecasts

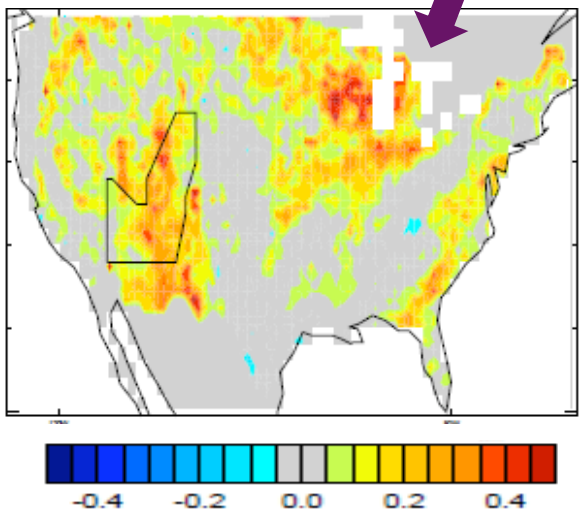
Linear regression analysis examining observed streamflow, snow, climate and soil moisture:



"This study demonstrates that available macroscale estimates of soil moisture have the potential to enhance streamflow prediction..."
(Berg and Mulroy, Hydro. Sci., 51, 642-654, 2006)



Contribution (r^2) of Jan. 1 soil moisture initialization to MAM streamflow prediction.



Synthetic analysis showing where soil moisture initialization may improve streamflow prediction at seasonal timescales. Results are supported by available streamflow observations.
(Mahanama et al., in preparation)

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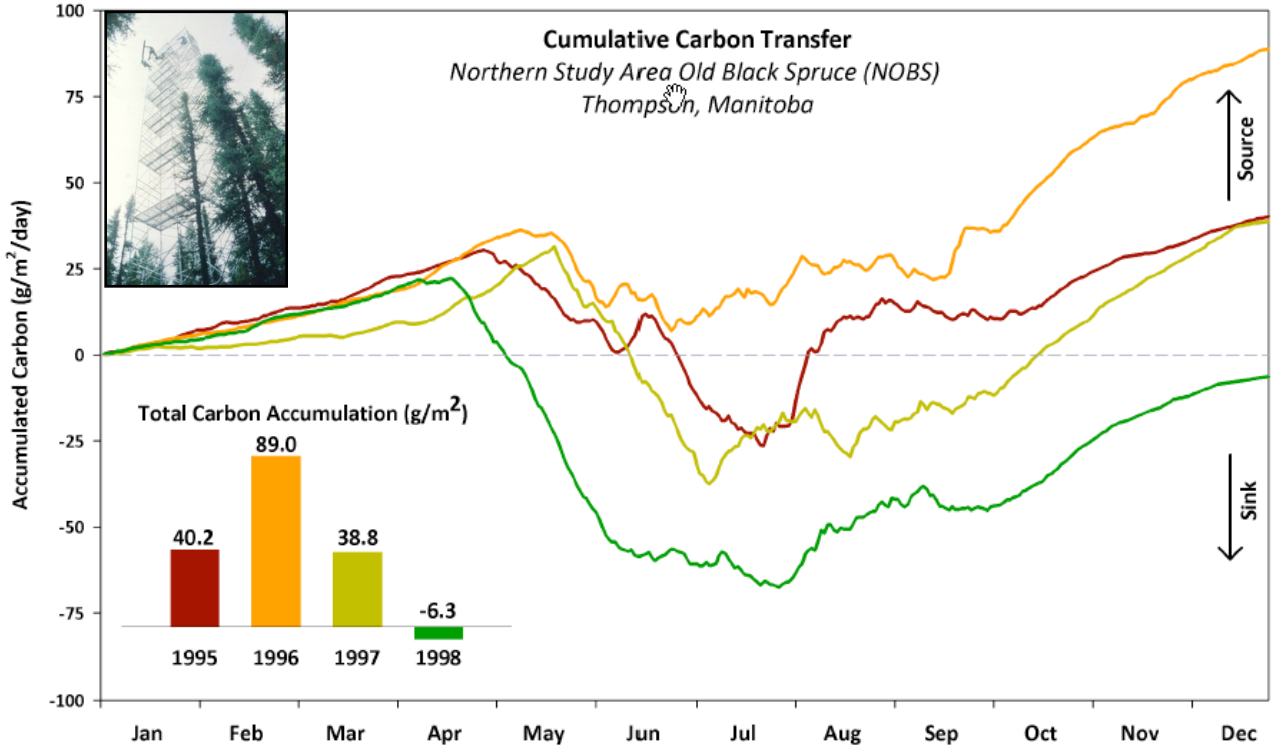
Science/Apps Driver: Carbon Budgets



5/7 5/27 5/26 4/22 Spring thaw dates

Normal to late thaw (May): Carbon Source [1995, 1996, 1997]

Early thaw (April 22): Carbon Sink [1998]

Goulden et al., 1998: Sensitivity of Boreal Forest Carbon Balance to Soil Thaw, *Science*, 279.

Herring, D. and R. Kannenberg: The mystery of the missing carbon, *NASA Earth Observatory*.

A given location can be a net source or net sink of carbon, depending on freeze/thaw date. SMAP freeze/thaw measurements can help reduce errors in the closing of the carbon budget.

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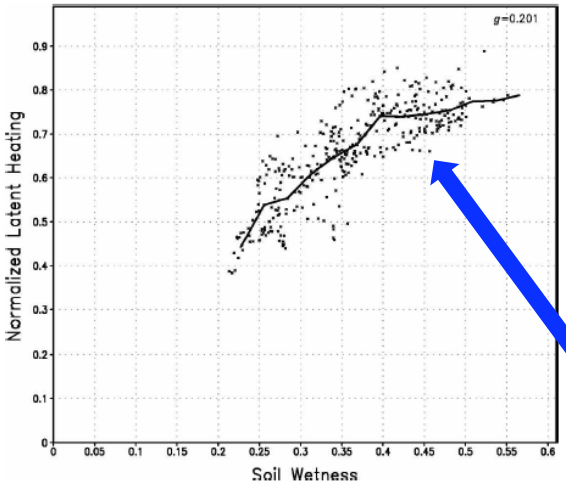
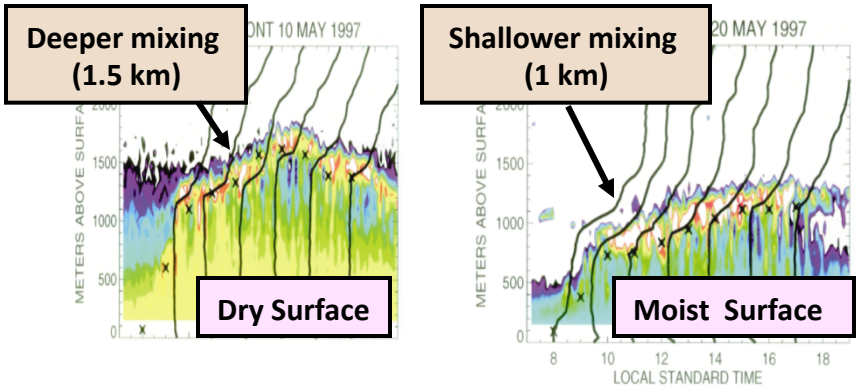
Science/Apps Driver: Land Model Development (Climate Studies, ...)

Soil moisture exerts control over the surface energy balance (wetter soil → more evaporation)...



Dirmeyer et al., J. Hydromet., 7, 1177-1198, 2006

... which in turn affects the evolution of the lower atmosphere.



LeMone et al., *BAMS*, 81(4), 757-779, 2000.

GCM representations of this function are essentially "guesses", given scarcity of soil moisture and evaporation data. Increases in data availability would let us hone this and other GCM representations, key to improving GCM simulations of (e.g.) climate change impacts.

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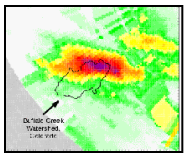
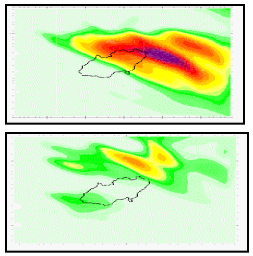
Science/Apps Driver: Miscellaneous

Short-term weather prediction



Observed

24-Hour P Forecasts →

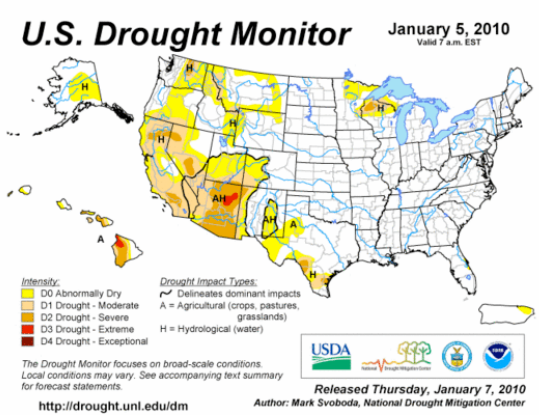


With Realistic Soil Moisture

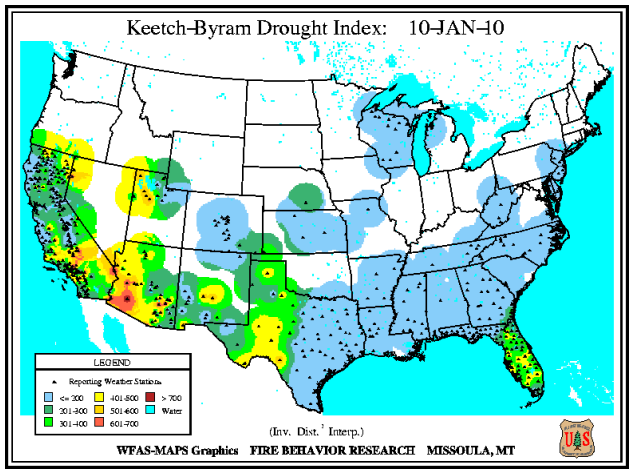
Without Realistic Soil Moisture

Chen et al., *J. Atmos. Sci.*, 58, 3204-3223, 2001.

Drought monitoring, forecasting



Fire danger



http://www.fs.fed.us/land/wfas/kbdi.gif

And more:

-- Crop forecasting
-- Flood danger
-- Ecosystem monitoring/ forecasting
-- Climate monitoring
-- etc., etc.

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SMAP Mission Concept

- L-band unfocused SAR and radiometer system with offset-fed 6-m light-weight deployable mesh reflector rotating about nadir axis (14.6 rpm)
  - Single feed (dual-pol radar and polarimetric radiometer)
  - Conical scan, fixed incidence angle across swath
  - Contiguous 1000 km swath
  - Radar resolution: 1-3 km (degrades over center 30%)
  - Radiometer resolution: 40 km
- Sun-synchronous dawn/dusk orbit
- Mission Ops duration 3 years

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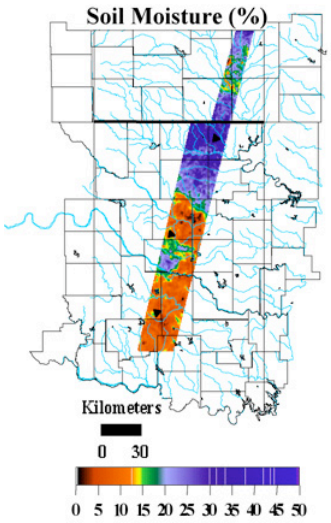
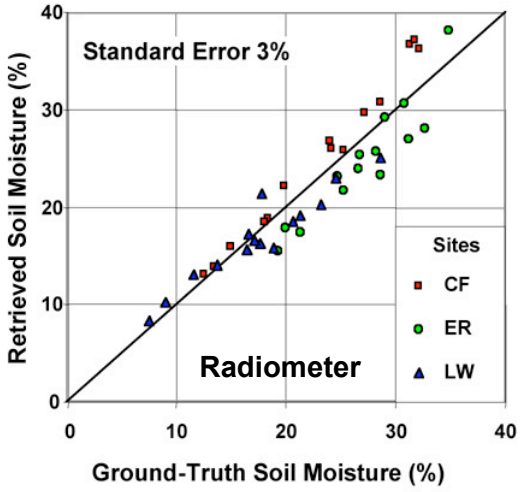
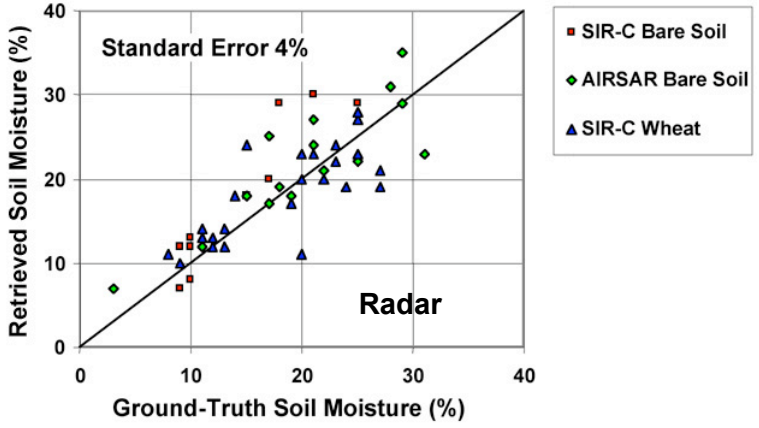
L-band Active/Passive Measurement Concept and Heritage

- Soil moisture retrieval algorithms are derived from a long heritage of microwave modeling and field experiments
  - MacHydro'90, Monsoon'91, Washita'92, FIFE, HAPEX, SGP'97,'99, SMEX'02−'05, SMAPVEX'08
- **Radiometer—**High accuracy (less influenced by roughness and vegetation) but coarser spatial resolution (40 km)
- **Radar—**High spatial resolution (1−3 km) but more sensitive to surface roughness and vegetation
- **Combined Radar-Radiometer** product provides optimal blend of resolution and accuracy to meet science objective







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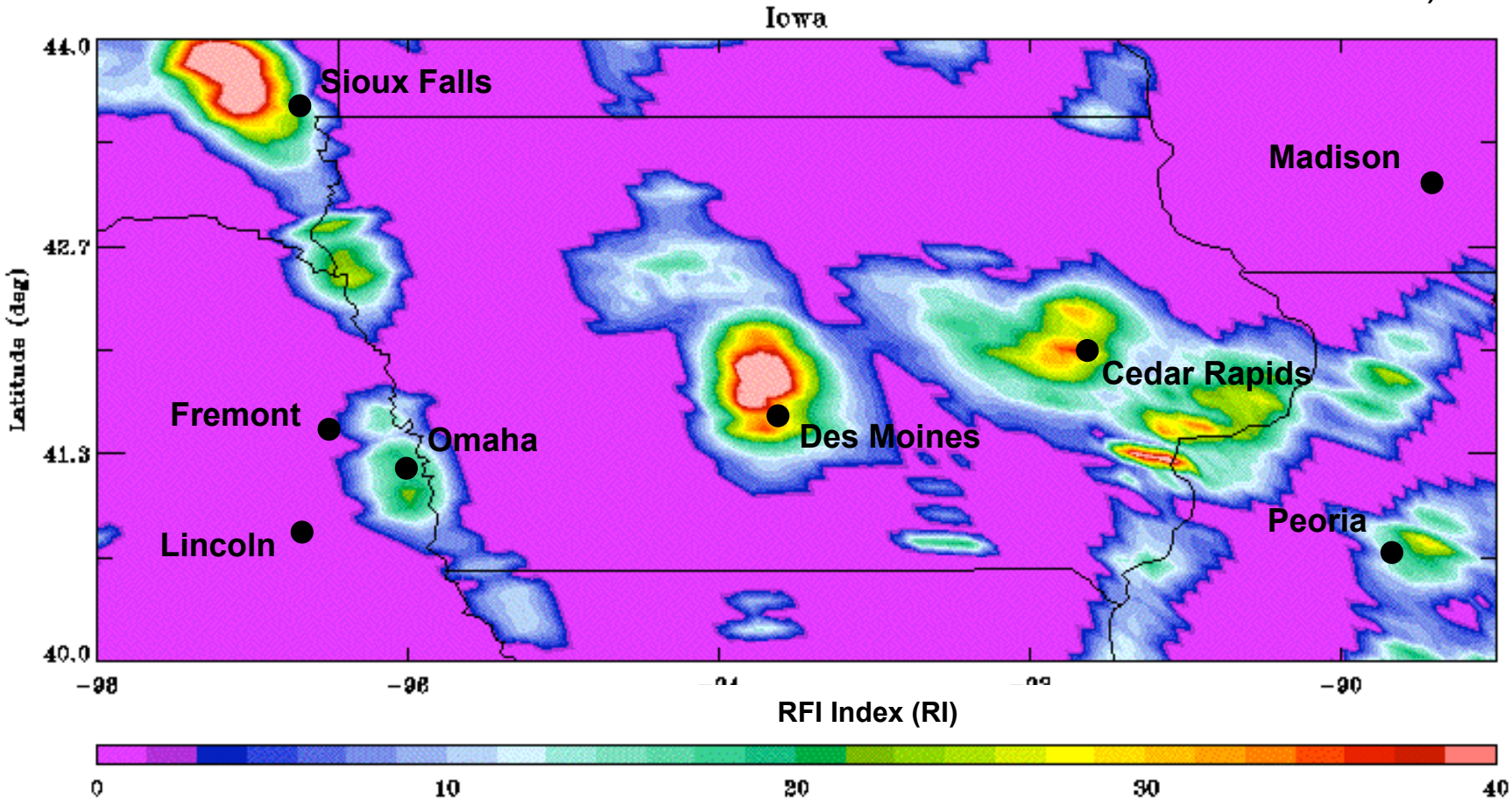
Anthropogenic Radio-Frequency Interference (RFI)

SMAP Radiometer designed to mitigate RFI

Example for 6 GHz (AMSR and MIS instruments)



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SMAP Baseline Science Data Products

Data Product		Spatial Resolution	Nominal Latency	
Short Name	**Long Name**			
L1B_S0_LoRes	Low Resolution Radar Backscatter (σ^o)	~ 30 km	12 hours	Global Mapping L-Band Radar and Radiometer
L1C_S0_HiRes	High Resolution Radar Backscatter (σ^o)	~ 1 – 3 km	12 hours	
L1B_TB	Radiometer Brightness Temperature (T_B)	~ 40 km	12 hours	
L1C_TB	Radiometer Brightness Temperature (T_B)	~ 40 km	12 hours	
L2_F/T_A	Freeze/Thaw State	~ 3 km	24 hours	High-Resolution and Frequent-Revisit Science Data
L2_SM_P	Radiometer Soil Moisture	~ 40 km	24 hours	
L2_SM_A/P	Radar/Radiometer Soil Moisture	~ 10 km	24 hours	
L4_C	Carbon Net Ecosystem Exchange	~ 10 km	14 days	Observations+Model Value Added Product
L4_SM	Surface & Root Zone Soil Moisture	~ 10 km	7 days	

Also: daily composites (Level 3 products) will be provided with 30 hr latency...

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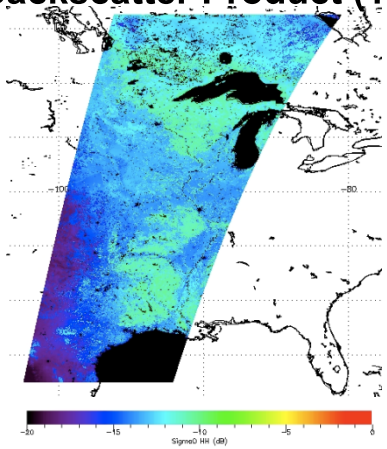
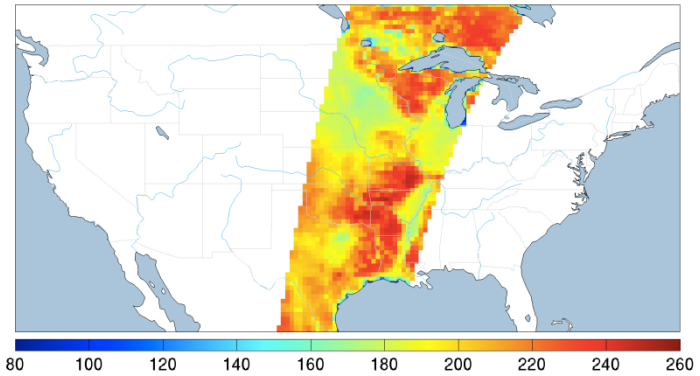
Algorithm Evaluation, Implementation in SMAP's End-to-End Simulation Testbed

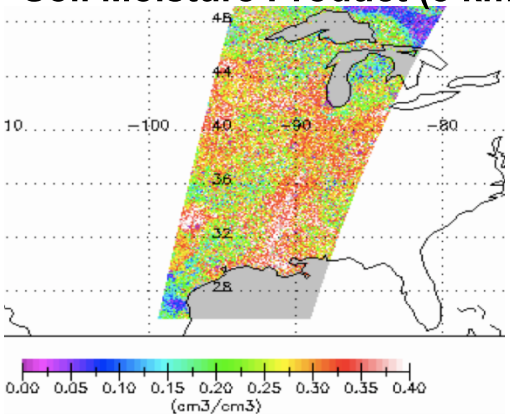
L1C_S0_Hi-Res Radar
Backscatter Product (1-3 km)



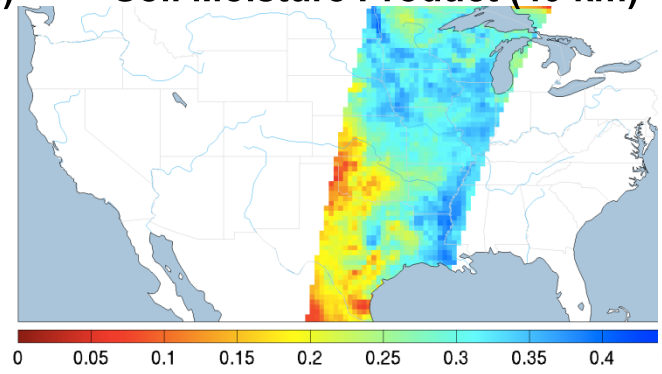
L1C_TB Radiometer
Brightness Temperature Product (40km)



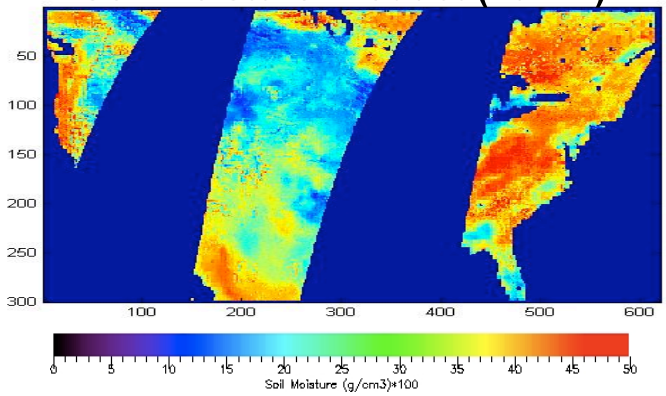
L2_SM_A Radar
Soil Moisture Product (3 km)



L2_SM_P Radiometer
Soil Moisture Product (40 km)



L3_SM_A/P Combined
Soil Moisture Product (10 km)



Summary

SMAP is an Earth science mission with:

-- High Science Returns (Water, Carbon and Energy Cycles)

-- High Applications Returns (Operational Hydromet Fx and Drought Monitoring)

Measurement and algorithms have matured with ground and airborne experiments, Hydros heritage

Current or upcoming activities:

- Focused Airborne Experiments on Active/Passive and Freeze/ Thaw
- Algorithm Testbed (Testbed to Transition to Science Data System)
- Engagement of Application Users

SMAP Working Groups

Working Groups have been established as a means to enable broad science participation in the SMAP mission. The working groups are led by Science Definition Team (SDT) members and provide forums for information exchange on issues related to SMAP science and applications goals and objectives. The working groups communicate via email and at meetings, conference sessions, workshops, and other venues. There are four current working groups:

1. Algorithms Working Group (AWG)

2. Calibration & Validation Working Group (CVWG)

3. Radio-Frequency Interference Working Group (RFIWG)

4. Applications Working Group (ApWG)

http://smap.jpl.nasa.gov